# Enersolve Demonstration Project

## Pre-Engineering Assessment

## Department of Supply and Services and Energy Mines and Resources Canada

March 1984
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March 27, 1984

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Attention: Mr. A.C.S yden

Dear Sirs:

PRE-ENGINEERING ASSESSMENT OF AN
ENERSOLVE DEMONSTRATION PROJECT

We take pleasure in forwarding the original and nine (9) copies of the final report of this study.

We appreciate the opportunity to work with you on this most interesting project and hope the results will ultimately contribute towards improved operations at Brunswick Smelting and elsewhere.

Yours very truly,
FENCO ENGINEERS INC.

Weldon Thoburn

Weldon Thoburn, P.Eng., Ph.D.
Chief Metallurgical Engineer

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REQ. NO. 3-9106-6

# PRE-ENGINEERING ASSESSMENT

# OF AN

# ENERSOLVE DEMONSTRATION PROJECT:

# BRUNSWICK MINING AND SMELTING's

# ACID PLANT GAS PRE-HEATER

# FOR

# SUPPLY & SERVICES CANADA

DS&S CONTRACT NO. OSQ83-00234

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## ABSTRACT

Fenco Engineers Inc. assessed the combustion and process efficiency aspects of the acid plant pre-heater at Brunswick Mining and Smelting as part of an energy conservation study in the Enersolve Demonstration Project series. An overall efficiency less than 50 percent was estimated for the pre-heater operation. That is, less than half the available thermal energy in the fuel is transferred to the process gases.

Methods considered to improve the efficiency of operations include recycling combustion stack gases, replacing the combustion system in part or completely, using alternate fuels, and recovering additional heat from process gas exiting the acid plant. Paybacks ranged from less than one to over five years.

## RÉSUMÉ

Fenco Engineers a évalué l'efficacité des systèmes de combustion et de traitement du préchauffeur de l'usine d'acide du complexe Brunswick Mining and Smelting dans le cadre d'une étude de conservation d'énergie rattachée au projet de démonstration Enersolve. Nous avons évalué à moins de 50% l'efficacité globale du préchauffeur; autrement dit, moins de la moitié de l'énergie thermique du combustible sert aux gaz du procédé.

Les méthodes considerées pour améliorer l'efficacité du préchauffeur sont les suivantes: recyclage des gaz de cheminée, remplacement du système de combustion en totalité ou en partie, utilisation de combustibles de remplacement, et récupération de la chaleur provenant des gaz de préchauffage utilisés et sortant des installations. Les périodes d'amortissement s'échelonnent de moins d'un an à plus de cinq ans.

## 1.0 SUMMARY

As part of the Enersolve series of energy conservation demonstration projects, Fenco Engineers carried out a study of the acid plant gas pre-heater at Brunswick Mining and Smelting. The B.M.&S. operation is located at Belledune, New Brunswick.

The site investigation produced data on an air-tempered Peabody combustion system including fuel use, combustion and overall heating efficiencies, and the cyclical nature of the process gas pre-heating requirement. No. 6 oil is fired producing a gross heat input of about 13 MJ/sec. Combustion system process settings are manual.

There were indications (soot and carbon monoxide) of unburned fuel in gases leaving the inner combustion chamber. Likely causes are a low air/fuel ratio and a low steam atomizing pressure. About one percent oxygen was measured at the combustion chamber outlet.

Based on the oxygen concentration in the tempered gas entering the pre-heater heat exchanger and the exhaust gas temperature, an overall efficiency of 48 percent was estimated. This was confirmed by a combustion/process gas heat balance.

The following schemes were reviewed to improve the fuel use and gas process heating efficiencies:

i) Recuperation of heat in the spent combustion stack gas through direct recycling.

ii) Replacing all or part of the pre-heater controls to optimize the warm-up and full fire combustion processes.

iii) Modifying the fuel system to eliminate or reduce steam by homogenizing with water.

iv) Recovering heat from spent warm-up gases using the acid plant "cold" heat exchanger through which both acid plant in-coming and out-going process gas steams normally pass.

v) An economical combination of a new pre-heater (Thermo-Transfer), recycling combination stack gas (Option i), and utilization of the cold exchanger as outlined in Option iv.

Table 1. outlines the costs and simple paybacks for the various improvements investigated. Options with attractive returns include the stack gas recycle and existing "cold" heat exchanger utilization schemes.

Options with attractive paybacks can be exploited quickly and therefore would not be redundant even if the existing pre-heater is replaced. (That is, Schemes 1A and 4). Maximum fuel efficiency is expected if Option 5 is adopted.

A detailed examination of the combustion system air supply should be undertaken to determine whether savings in power can be made by simplifying the ducting.

TABLE 1.1

SUMMARY OUTLINE OF ENERGY EFFICIENCY SCHEMES AND COST DATA

| Option | Description | Capital* Cost $ | Fuel Savings $/yr. | Simple Payback (yr.) | Cost for 9** month monitoring |
|---|---|---|---|---|---|
| 4.2.A | Recycle Stack Gas | 123,700. | 91,500. | 1.35 | 18,000. |
| 4.2.B | Install High Efficiency Pre-heater | 586,300. | 117,100. | 5.0*** | 30,000. |
| 4.3 | Up-grading Combustion System and Controls | 90,000. | 7,320. | 12.2 | N.A. |
| 4.4 | Alternate Fuel-homogenized No. 6 Oil | Not Persued | | | |
| 4.5 | Recovering Heat Using "Cold" Heat Exchanger | 68,200. | 73,300. | 0.93 | 15,000. |
| 4.6 | Combination of new pre-heater, stack gas recycling, and utilization of the "cold" exchanger | 654,500. | 190,400. | 3.4 | 20,000. |

* The installed costs including engineering are order of magnitude.
** Monitoring program by engineering group external to operations.
*** This is conservative because it does not consider the increased maintenance and possible need to replace the existing system in the next few years.

## 2.0 INTRODUCTION

In January 1984 Fenco Engineers Inc. was awarded one of six studies under the auspices of CANMET's Enersolve Demonstration Project series. Evaluation of the acid plant gas pre-heater operation at Brunswick Mining and Smelting (B.M.&S.), located at Belledune, New Brunswick, formed the first phase of the project. Collection of process data sufficient to characterize the combustion process and system efficiencies was included. Analyses of methods to up-grade the performance of the pre-heater operation formed the second phase. Development of retrofit project costs and subsequent monitoring costs to determine the effectiveness of the installed systems formed the final phase.

This report outlines the results of the plant survey work and the recommendations, including costs, to improve the efficiency of the pre-heater operation.

## 3.0 ASSESSMENT OF ACID PLANT PRE-HEATER OPERATION

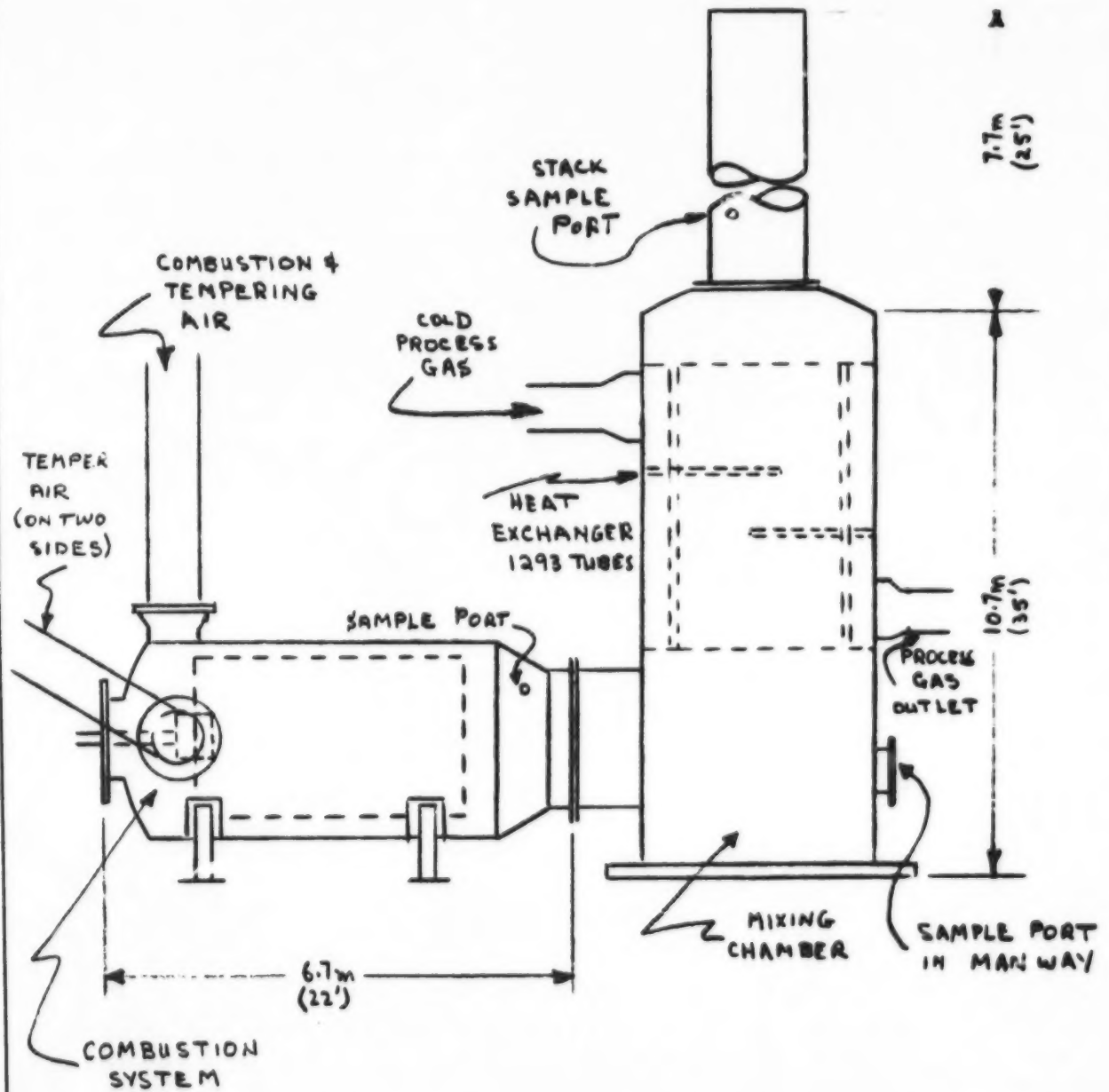
### 3.1 Background Discussion of Pre-heater Operation in a Typical Plant

Processing of gases containing 4.5 to 5 percent sulphur dioxide to produce sulphuric acid is autogenous when the $SO_2$ to $SO_3$ converting vessel is operated at about 450°C. Gases available from metallurgical smelting and roasting operations are cleaned, scrubbed, and humidified and typically enter the acid plant processing section at 30° to 40°C. This cooled gas is re-heated with hot gas from the converter by indirect heating in heat exchangers, supplemented when required by additional indirect heating in a pre-heater heat exchanger. Operation of the pre-heater is required during start-up and in the case of operations processing sulphur dioxide bearing gases with concentrations below about 4.5 percent. (Refer to Figure 4.5.1 for more details).

### 3.2 Pre-heater Operation at Brunswick Mining & Smelting

The acid plant at B.M.&S. processes gases produced during sintering of lead concentrate. Strength of the incoming gases is typically 5 to 5.5 volume percent $SO_2$ permitting autothermal operations following start-up. Pre-heating during start-up is achieved in a vertical shell and tube type heat exchanger. Process gases flow through the shell side and air tempered combustion products through the tubes. Spent heating gases vent directly to atmosphere through a stack over the heat exchanger. The combustion chamber, mixing chamber, heat exchanger and stack are shown in Figure 3.2.1.

The combustion chamber consists of a conventinal multifuel gun burning No. 6 oil and firing into an inner refractory lined chamber. Tempering air flows through an outer annulus and combines with the combustion products in a mixing chamber below the heat exchanger.

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PROJECT TITLE

ACID PLANT GAS PRE-HEATER

| | CODE | DWG. |
|---|---|---|
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The combustion system is a Peabody design circa 1970 utilizing steam for atomization. A summary of design and operating parameters is outlined in Table 3.1.1. Measurements of the oxygen and carbon monoxide in the products of combustion indicate the air/fuel ratio is lower than typically required for maxium fuel combustion and efficiency. The oxygen measurement suggests the combustion process is operating with about 5 percent excess air. In addition, the steam pressure and high steam-oil differential pressure may have aggravated the incompleteness of combustion through inadequate atomization.

Operational setting of the combustion air and fuel rates is manual at B.M.&S. Instruments to accurately measure air, fuel, or the composition products are not in place. Air and fuel flows are set by temperature and visual observation of the stack plume. Dilution of the combustion products from 1.2 to about 16 percent oxygen by the tempering air tends to mask indications of incomplete combustion making visually based adjustments difficult.

Soot deposits collected in the gas sampling train qualitatively confirm the air deficiency and possible inadequate atomization.

## 3.3 Condition of the Pre-heater

The cyclical nature of the pre-heater operation produces severe thermal cycling within the combustion system and the heat exchanger. Operation of the pre-heater follows weekly maintenance programs and unscheduled shutdowns of sufficient duration to chill the acid plant converter vessel. The time required for pre-heating during the winter, from $-20^{o}C$ or colder to $600^{o}C$, ranges one to three hours depending on the urgency to process gases from the sinter plant.

However, the combustion system remains functional although the controls have somewhat deteriorated. As mentioned, operation of air and fuel settings is manual.

TABLE 3.1.1

ACID PLANT PRE-HEATER: SUMMARY OF OPERATING AND DESIGN PARAMETERS

| Item | Design | Typical | This Study |
|---|---|---|---|
| No. 6 Fuel Oil High Heat Value (kJ/l) | - | 42425 | 42425 |
| (BTU/I Gal) | - | 182,000 | 182,000 |
| Full Fire Rate (l/hr) | 1423 | 1137 | 1077 |
| (IGP.H.) | 313 | 250 | 245 |
| Heat Duty (MJ/sec) | 16.2 | 13.4 | 13.1 |
| (BTU/hr) | $55 \times 10^6$ | $45.5 \times 10^6$ | $44.5 \times 10^6$ |
| Peabody Oil Burner (Model) | M-21 | Thor-Flame | Thor-Flame |
| Oil Pressure (kPa) | 759 | 1000 | 965 |
| (psig) | 110 | 145 | 140 |
| Atomizing Steam (kPa) | 827 | 724 | 586 |
| (psig) | 120 | 105 | 85 |
| (kg/kg oil) | - | | 0.05▽ |
| Steam-Oil Differential (kPa) | 138 | 276 | 379 |
| (psig) | 20 | 40 | 55* |
| Combustion Air ($Nm^3/m$) | 393 | - | - |
| (NCFM) | 13,900 | - | - |
| (°C) | -25 to 30 | - | -20 |
| Tempered Combustion Gases (°C) | 595 | 600 | 589 |
| % $O_2$ | - | - | 16.0△ |
| Stack Combustion Gases (°C) | 349 | 350 | 317 |
| ($Nm^3/m$) | - | - | 1056 |
| (NCFM) | - | - | 37,300 |
| Combustion Chamber (% $O_2$) | - | - | 1.2** |
| (ppm $CO_2$) | - | - | >500** |
| Process Gas Shellside ($Nm^3/min$) | 425 | | |
| (NCFM) | 15,000 | - | - |
| (Inlet °C) | 50 | - | 30 |
| (Outlet °C) | 450 | 450 | 438 |
| Annual Oil Use (l/yr) | | | |
| (I Gal/yr.) | - | 367,000 | - |
| ($1 yr.) | - | 366,000• | - |
| Annual Operation (hr/yr.) | - | ~1450 | - |

* reversed from design requirement

** gas prior to mixing with tempering air-measured with Lynn 6100 combustion analyser utilizing a gel-type electrochemical cell for oxygen measurements. Scale display is linear from 0 to 25 percent $O_2$ readable to nearest 0.25 percent. CO measured with Lynn CO detector tube (similar to Dregger device) capable of displaying 0 to 500 ppm CO.

△ average of 10 measurements across the mixing chamber

▽ estimated based on typical burner operations

• Unit rates shown in Appendix D.

Thermal cycling has resulted in problems around the heat exchanger hotside tubesheet exposed to the mixing chamber. Cracks in and between the lower tubesheet and shell have developed that cannot be seal welded. Damage to the lower expansion bellows frm weld repairs to the tubesheet requires an outer expansion casing over the original joint. Tubesheet rolled joints have failed requiring tube plugging. As a result, small amounts of process gas escape into the stack gas. The gas pre-heater is the first unit operation downstream of the main acid plant blower operating at just below 100 in.w.c. Internal leaks in the heat exchanger contaminate the stack gas with $SO_2$.

## 3.4 Overall Pre-heater Efficiency

Combustion efficiency in the inner combustion chamber is less than optimum because of the presence of significant amounts of CO and unburned fuel in the products of combustion in the inner combustion chamber. The ultimate combustion of the unburned components after mixing with tempering air could not be accurately determined.

On a complete combustion basis and 16 percent oxygen in the tempered hot gas, and a stack temperature of 320°C, the available heat from the pre-heater is approximately 48 percent [1] as outlined in Table 3.4.1.

A comparison of the stack gas volume and temperature with an estimate of process gas flow supports the efficiency of 48 percent as outlined in Appendix C. This estimate is considered approximate due to the inclusion of two additional gas sources in the stack gas volume measured by the pitot tube method. A rain shedding gap in the stack allowed air to infiltrate. Process gas, leaking from the high pressure shell side of the heat exchanger, also added to the stack gas volume.

The composition of the blended and tempered gases in the mixing below the heat exchanger represents the better means of estimating the efficiency of the pre-heater.

TABLE 3.4.1

SUMMARY OF PRE-HEATER EFFICIENCY ESTIMATE

| LOSS ITEM | % |
|---|---|
| Dry Gas Heat Loss | 42.5 |
| Hydrogen Loss | 6.8 |
| CO Loss* | 2. |
| Moisture Loss | 0.5 |
| TOTAL | 51.8 |

Overall Efficiency = 100 - 52 = 48%

* estimate only based on rapidity of test cell CO reaction.

## 4.0 ENERGY CONSERVATION ANALYSES AND RETROFIT POSSIBILITIES

### 4.1 Summary of Conservation Methods

The following conceptual improvements to the operation of the gas pre-heater were evaluated in this study:

i) Recuperation of heat in the spent stack gas through direct re-cycling.

ii) Replacing part or all of the pre-heater combustion system to optimize the warm-up and full-fire combustion processes.

iii) Modifying the fuel system to eliminate or reduce steam by homogenizing the fuel oil with water.

iv) Recovering heat from the spent process warm-up gases using the acid plant "cold" heat exchanger through which both acid plant in-coming and out-going process gas streams normally pass. This would shorten the time to pre-heat and minimize the sulphur dioxide contained in process gases which are emitted to atmosphere during the warm-up period.

v) Combining a new pre-heater, recuperation of spent stack gas through re-cycling, and utilization of the acid plant "cold" heat exchanger (Option iv).

Additional capital for improved efficiency pre-heaters is normally hard to justify in acid plants which shutdown infrequently. However, the regular maintenance schedule at B.M.&S. involving weekly start-ups, results in the potential for significant fuel savings.

## 4.2 Direct Re-Cycling of Stack Gas

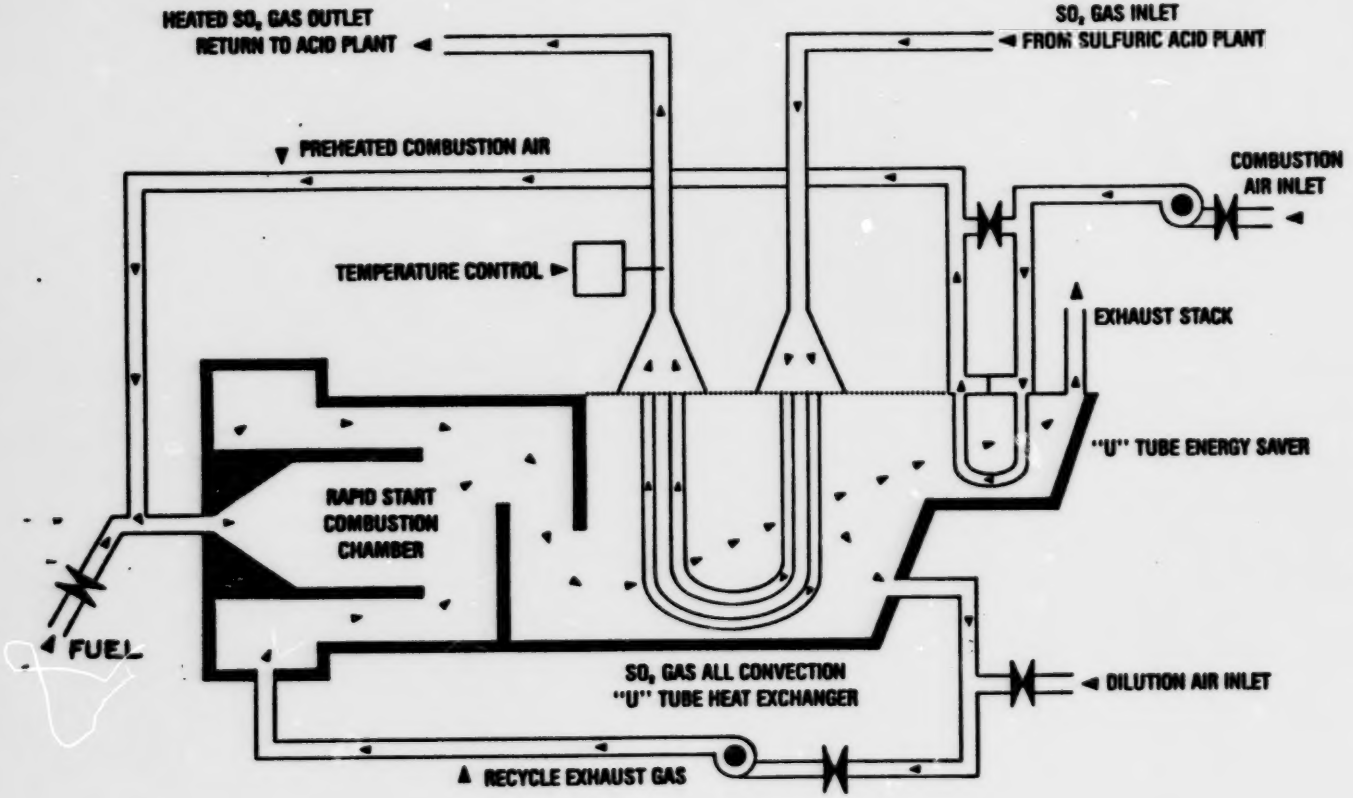
Efficiency of heat utilization in the pre-heater was shown to be less than 50 percent in Section 3. The heat in the stack gas can be directly re-cycled with appreciable savings. Acid plant package pre-heaters can be purchased with re-cycle of stack gas and pre-heating can be purchased with re-cycle of stack gas and pre-heating of combustion air features built-in. A schematic of a commercial[2] unit in Figure 4.2.1 shows both exhaust gas re-cycling and combustion air pre-heating. Tube bundles of a U-tube design and insulated tubesheets reduce thermal shock during warm-up.

Table 4.2.1 illustrates the cost and estimated fuel savings expected for re-cycling part of the stack gas by modifying the existing equipment. For comparison, the cost of replacing the existing unit with a pre-heater, including a stack gas re-cycle option, operating at an overall 77 percent efficiency is also included. An equipment list for both options is shown in Appendix D.

TABLE 4.2.1: SUMMARY OF COSTS

FUEL SAVINGS AND SIMPLE PAYBACK FOR STACK GAS HEAT RECUPERATION SCHEMES

| | Option | Cost $ | Fuel Savings l/yr. | Fuel Savings $/yr. | Simple Payback (yr.) |
|---|---|---|---|---|---|
| 4.2.A | Modify Existing Pre-heater | 123,700. | 416,900 | 91,500. | 1.35 |
| 4.2.B | New Pre-heater Unit (77% Efficiency) | 586,300. | 533,600 | 117,100. | 5.0 |

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## 4.3 Up-Grading of the Pre-heating Combustion System

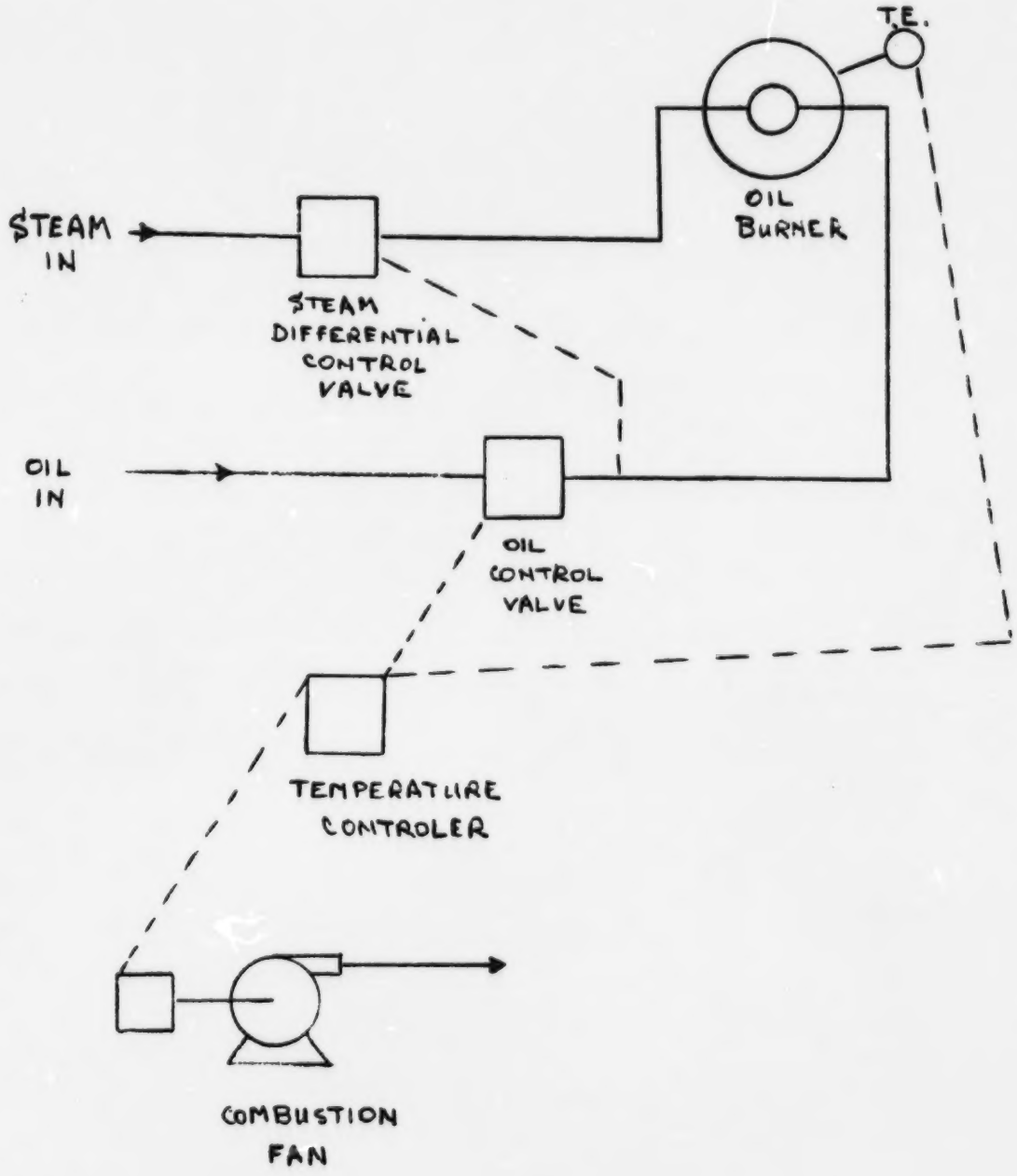
The current operation of the pre-heater combustion system requires manual setting of oil and air rates during both start-up and full firing. As noted in Section 3, visual observation of the stack gas opacity is used to establish the apparently best combustion condition.

The fuel savings that could be expected with better combustion controls and a state of the art burner are difficult to predict. The efficiency might be expected to improve by about 2 percent. This is only an estimate based on CO in the products of combustion at a level of 2000 ppm to illustrate the cost effectiveness of new controls. Measured CO concentrations greater than 500 ppm were reported in Table 3.1.1. A block diagram of the modified system is shown in Figure 4.3.1. New equipment included in the revision are listed in Appendix D.

TABLE 4.3.1: SUMMARY OF RETROFITTING NEW COMBUSTION CONTROLS AND BLOWER

| | Option | Cost $ | Fuel Savings l/yr. | Fuel Savings $/yr. | Simple Payback (yr.) |
|---|---|---|---|---|---|
| 4.3 | Blower & Controls | 90,000. | 33,349 | 7,320. | 12.2 |

Replacement of the combustion controls and installation of a separate combustion air blower are not attractive since elimination of CO can alternately be achieved by establishing acceptable combustion conditions by monitoring the combustion products and making necessary adjustments.

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ACID PLANT PREHEATER MODIFIED COMBUSTION CONTROLS SYSTEM

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## 4.4 Evaluation of Alternate Fuels and Firing Methods

Steam production at Brunswick decreases dramatically during summer months. A single boiler is maintained at low fire to supply steam to minor users such as the acid plant pre-heater. Elimination of the pre-heater steam demand would assist in closing out the boiler operation two to three months per year.

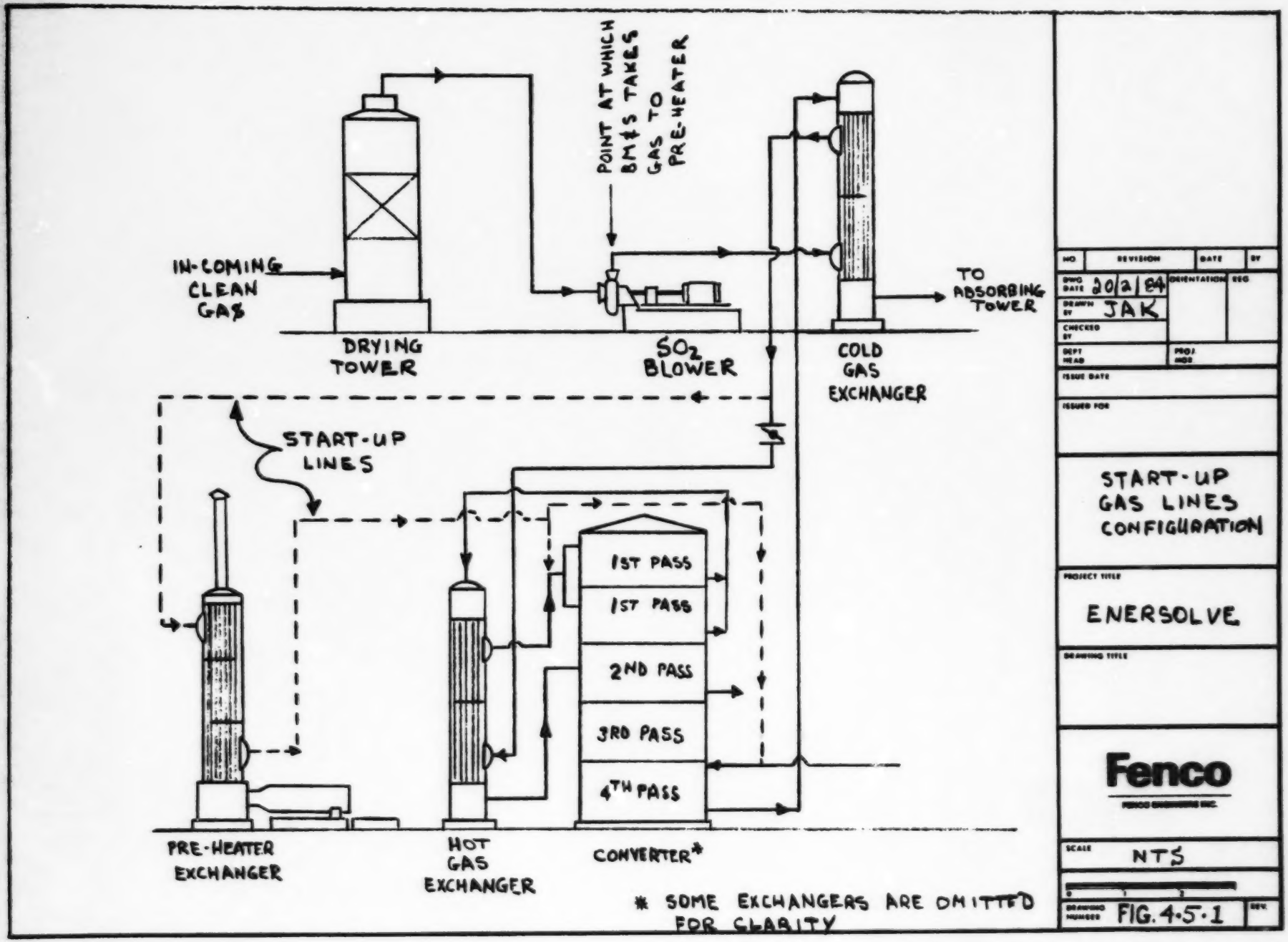
Evaluations of firing with homogenized oil/water emulsions as a means of reducing the atomizing steam requirement and producing a cleaner burn were inconclusive.

Discussions with suppliers [4,5] yielded somewhat guarded suggestions of possible improvements in the pre-heater case. Other oil fired combustion systems which can improve with markedly lower air/fuel ratios or cleaner heat transfer surfaces may benefit from homogenized water additions.

No further assessment of this option was persued.

## 4.5 Recovering Heat from Spent Warm-Up Gases Produced during the Pre-heat Cycle

In typical acid plant configurations a heat exchanger recovers heat from process gases prior to absorbing. This is termed the "cold" exchanger. Incoming cold process gas is routed through the shell side of this exchanger during normal operations. Recent acid plant design utilizes this concept during pre-heating as well by passing air or process gas through this exchanger prior to further heating in the pre-heater exchanger (similar to the one examined in this study). A simple diagram showing this process arrangement is outlined in Figure 4.5.1. As the plant warms up, the cold incoming gas extracts heat from the outgoing gas on the tube side which would otherwise ultimately lose its heat to atmosphere via the plant cooling tower.


POINT AT WHICH BM#S TAKES GAS TO PRE-HEATER
IN-COMING CLEAN GAS
DRYING TOWER
$SO_2$ BLOWER
COLD GAS EXCHANGER
TO ABSORBING TOWER
START-UP LINES
1ST PASS
1ST PASS
2ND PASS
3RD PASS
4TH PASS
PRE-HEATER EXCHANGER
HOT GAS EXCHANGER
CONVERTER*
* SOME EXCHANGERS ARE OMITTED FOR CLARITY
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For calculation purposes, the cold incoming gas is assumed to heat in the "cold" exchanger from 30°C at the start of a warm-up to 200°C after two hours. This is a typically observed time-temperature relationship for acid plants [2]. Fuel savings, estimated for this option, are equivalent to the heat in the in-coming gas picked up in the "cold" exchanger. This is conservative as overall fuel use efficiency is ignored.

Table 4.5.1 summarizes the cost of gas ducting changes and expected fuel savings. A summary of equipment for the option is shown in Appendix D.

TABLE 4.5.1: SUMMARY OF COSTS AND PAYBACK FOR HEAT RECOVERED USING THE EXISTING COLD EXCHANGERS

Option 4.5

| Capital Cost $ | Estimated Fuel Savings | | Simple Payback (yr.) |
|---|---|---|---|
| | % | $/Yr. | |
| 68,200. | 19.5 | 73,300. | 0.93 |

## 4.6 Combination of a New Pre-heater, Re-Cycling Stack Gas, and Utilization of the Cold Exchanger

Maximum fuel efficiency is expected following installation of a new pre-heater having stack gas re-cycle capability in combination with utilization of the "cold" exchanger. These options are described in Sections 4.2 and 4.5 respectively.

The fuel savings and costs for the combination scheme are outlined in Table 4.6.1. Equipment requirements are listed in Appendix D under Options 4.2 and 4.5.

TABLE 4.6.1

SUMMARY OF COSTS, FUEL SAVINGS, AND PAYBACK FOR A NEW PRE-HEATER COMBINED WITH THE COLD EXCHANGER OPTION

| | Option | Cost $ | Fuel Savings l/yr. | Fuel Savings $/yr. | Simple Payback (yr.) |
|---|---|---|---|---|---|
| 4.6 | Combination of New Pre-heater and Use of the "Cold" Exchanger | 654,500. | 867,430. | 190,400. | 3.4 |

## 5.0 REFERENCES

1. Combustion Efficiency Curves, CANMET, Ottawa, 1984.

2. Farrier Inc., Acid Plant Gas Heater description and budget price, February 1984.

3. Canadian Recuperators Ltd., Acid Plant Gas Heater Description, January 1984.

4. COMIXX Canada Ltd., Hudson, P.Q., "Emulsofier" homogenizer discussions, March 1984.

5. Power Corporation Inc., homogenizer discussions March 1984.

# APPENDIX A

## ESTIMATE OF FUEL USE DURING SITE SURVEY

B.M.&S. Store No. 6 oil for the acid plant pre-heater in a horizontal square and cylinder with a capacity of 45,500 litres (10,000 Igal) (B.M.&S. Drawing R-5750-1).

Fuel use during operations was estimated by dipping the tank with 4.9 m (16 foot) 2 x 2's. Fuel consumption for the entire run was estimated to be 3,205 litres.

During start-up of the pre-heater the fuel use was taken to be 45% of the full fire rate. On this basis the full fire operating oil rate was 1114 lph (245 IGPH).

$$1.42\ (\text{hr.}) \times (0.45\ X) + 2.25X = 3{,}205$$

$$X = 1{,}114$$

where $X$ = oil rate in lph.

This compares reasonably with the nominal oil use rate of 1,137 lph (250 IGPH).

# APPENDIX B

## UNIT RATES AND CONDITION SPECIFICATIONS USED IN THIS STUDY

| | | |
|---|---|---|
| Fuel Oil Costs, No. 6 ($/l) | | 0.2195 |
| Electrical Engery (¢/k Wh) | | 3.8 |
| Steam ($/1000 kg) | | 15.4 |
| Gas Conditions NTP | | 1 atmosphere<br>$0^{o}$ Celcius |
| Typical Characteristics of B.M.&S. No. 6 Oil: | | |
| Assay wt.% | S | 2.7 |
| | V | 0.024 |
| | Na | 0.003 |
| API $^{o}$ | | 6.5 to 11.9 |
| SSU Viscosity | | 310 (at $122^{o}$F) |

# APPENDIX C

## COMBUSTION/PROCESS GASES

## HEAT BALANCES

In an effort to substantiate the process information collected a heat balance was calculated by comparing the heat lost by the combustion gas with the heat gained by the process gas.

| Estimated Composition | | | Heat Loss Across Heat Exchanger ($\Delta t = 590 - 320^{o}C$) |
|---|---|---|---|
| Component | Vol. % | Kg/min. | kJ/sec |
| $O_2$ | 16 | 219 | 1,009 |
| $N_2$ | 79 | 945 | 4,818 |
| $CO_2$ | 4 | 109 | 548 |
| $H_2O$ | 1 | 8 | 75 |
| TOTAL: | 100 | 1,268 | 6,450 |

Available Heat = 0.95 x 6,450
= 6,125 kJ/sec.

| Incoming Process Gas | | | Estimated Flow for Available Heat and $\Delta t$ = 440 - 30°C | |
|---|---|---|---|---|
| Component | Vol. % | kg/min. | kJ/sec. | $Nm^3$/min. |
| $SO_2$ | 5.5 | 100 | 455 | - |
| $N_2$ | 78 | 620 | 4,675 | - |
| $O_2$ | 16.5 | 150 | 995 | - |
| TOTAL: | 100 | 870 | 6,125 | 635 |

The calculated gas flow of 635 $Nm^3$/min. compares with a plant measured flow of 764 $m^3$/min. at the blower outlet equivalent to about 708 $Nm^3$/min. The difference is within the error of the pitot tube measurement and necessary ingress air corrections.

# APPENDIX D

## SUMMARY EQUIPMENT LISTS FOR ENERGY CONSERVATION OPTIONS

| Option 1 | Equipment | No. |
|---|---|---|
| 4.2A | Hot Gas Fan & Drive 30HP | 1 |
| | Hot Gas Valve | 1 |
| | Ducting 83 cm ø | 1 lot |
| | Fittings & Ducting Modifications | 1 lot |
| 4.2B | Thermal Transfer Pre-heater (c/w stack gas recycle feature) | 1 |
| | Foundation Modifications | 1 lot |
| | Ducting Modifications | 1 lot |
| 4.3 | Temperature Controller (2 loop) | 1 |
| | Combustion Air Fan c/w Damper | 1 |
| | Oil Flow Control Valve | 1 |
| | Steam Oil Pressure Differential Controller | 1 |
| | Miscelleneous Piping, Tubing, Fittings | 1 lot |
| 4.5 | Hot Gas Valve | 1 |
| | Hot Gas Ducting | 1 lot |
| | Fittings & Ducting Modifications | 1 lot |